HE
203
.A56
no.
84-30

S Department
Transportation

Transportation Energy Management

Fuel Conservation in The Transit Revenue Fleet

DEPARTMENT OF
TRANSPORTATION
OCT 30 1984
LIBRARY

February 1984

HE
203
.A56
no.
84-30

Transportation Energy Management:

Fuel Conservation in the Transit Revenue Fleet

February 1984

DEPARTMENT OF TRANSPORTATION
OCT 30 1984
LIBRARY

Prepared by
Municipality of Metropolitan Seattle

Prepared for
Office of Planning Assistance
Urban Mass Transportation Administration
Washington, D.C. 20590

Distributed by
Technology Sharing Program
Office of the Secretary
U.S. Department of Transportation
Washington, D.C. 20590

DOT-I-84-30

ACKNOWLEDGMENTS

This manual was prepared by the energy section of the Municipality of Metropolitan Seattle (Metro) -- Alan J. Gibbs, executive director; Ronald J. Tober, director of transit. The principal authors are Lloyd David and Bonnie Berk. Critical technical assistance was provided by Scotty Conyne and Doug Daniels of Metro's Vehicle Maintenance Division. Mary Stanton provided invaluable clerical support. Financial assistance for this manual was provided by the federal Urban Mass Transportation Administration under the direction of UMTA Project Officer Richard Steinmann. The views expressed herein do not necessarily reflect those of the federal government.

February, 1984

FUEL CONSERVATION IN THE TRANSIT REVENUE FLEET

EXECUTIVE SUMMARY

INTRODUCTION — This manual is a practical guide to reducing fuel consumption in the transit revenue fleet. It is written for maintenance managers and planners responsible for maintenance and cost-efficiency issues. The manual describes concrete low-cost steps that can be taken to yield modest, yet significant, fuel and budget savings. Not all of the suggestions discussed here will be appropriate for every transit system, but every system should be able to achieve fuel savings of 5 to 20 percent by implementing actions discussed in this manual. The manual is divided into four sections, each of which is summarized below.

DEVELOPING A FUEL-CONSERVATION PROGRAM — The first step of a conservation program is to implement a system for measuring miles per gallon (MPG) for each coach in the fleet. This can be done manually or with mainframe or microcomputers. "Before" and "after" MPG measurements will indicate the effectiveness of a fuel-conservation program and are needed to test various fuel-saving techniques before implementing them. On the average, a transit coach consumes more than $10,000 worth of fuel per year. A 1-percent improvement in fleet MPG will save $100 per coach per year; a 10-percent gain saves $1,000 per coach per year.

The fuel-conservation techniques discussed in this manual fall into two categories: (1) those that can be implemented with a test and a decision, such as installation of new equipment; and (2) those that require regular action on the part of front-line staff, such as changed routine maintenance procedures. If the fuel-saving strategies of the first category are selected, responsibility for the program should probably rest with the managers responsible for assessing alternatives and making decisions. However, if any techniques are pursued that require changes in routine procedures, some sort of broader participation in the organization and implementation phase is recommended. Experience shows that if the workers ultimately responsible for carrying out a program are involved in its formulation, their commitment to the program will be much higher.

MAINTENANCE AND EQUIPMENT STRATEGIES — Interviews with maintenance managers and a literature review identified a number of techniques that could improve fuel economy. The following items are discussed in the manual:

- An aggressive tune-up program that can improve fleet MPG by 2 to 4 percent. This manual discusses a new, performance-based system for scheduling tune-ups.
- Regular tire pressure checks and a policy of inflating tires when the pressure is three pounds per square inch (psi) below the manufacturer's recommended level. Underinflated tires mean more energy consumption to overcome rolling resistance.
- Use of manometers to check air filters.
- Engine rebuilds between 250,000 and 300,000 miles.

- Replacement of fuel injectors, usually to smaller sizes, resulting in more efficient burning of fuel without a significant loss of power, especially for highway vehicles.

- Conversion to radial tires on highway vehicles which could improve MPG by approximately 3 percent.

- Maintenance of throttle delays to reduce excessive fuel use during acceleration without significantly reducing power.

OPERATIONS STRATEGIES — A number of trucking companies have had great success with programs that promote fuel-efficient driving habits. Some have shown increases in fleet MPG of more than 20 percent. Drivers should be targeted as a central component of any fuel-conservation program. To succeed, such a campaign requires both good training and consistent efforts to communicate program goals and motivate drivers. Key driving habits include smooth starts and stops, defensive driving and elimination of unnecessary idling during layovers.

Savings of 1 to 2 percent can be achieved by switching from No. 1 diesel to No. 2 diesel, which has a higher BTU content per gallon. Identifying a set of coaches to be used exclusively in highway service will permit the implementation of other fuel-conservation measures, such as use of radial tires, which would not otherwise be cost-effective.

PROCUREMENT STRATEGIES — The specifications for a bus purchase can greatly increase the fuel efficiency of the fleet. Among the factors that should be considered are air-streamlining, temperature sensitive fans, turbocharged engines and lightweight materials. Evaporative cooling technology is now being tested as a possible substitute for air-conditioning units, which substantially reduce MPG.

CONCLUSION — This manual will identify a number of possible ways to reduce fuel consumption in a revenue fleet. Some are complex and require time to implement; others require a decision and simple changes. Some can save hundreds of dollars per coach, while others will make only a modest difference.

The basic recommendation, in simple terms, is "Go try something." None of the measures discussed in this manual will save any fuel until they are implemented. The best approach is to pick one or two measures that seem appropriate, try them and test them if necessary -- but do so soon.

SUMMARY OF FUEL CONSERVATION MEASURES

Measure	Estimated % Savings (if available)	Ready for Implementation or Requires Testing	Ease of Implementation 1-Easy; 2-Moderate; 3-More Difficult
MAINTENANCE & EQUIPMENT STRATEGIES			
* Tune-up Program	2-4%	Ready for Implementation	2-Requires monitoring of results and schedule adjustments.
Tire Pressure Checks	2 lb. psi underinflation reduces MPG by 1%	Ready for Implementation	1
Manometer Air Filter Checks		Ready for Implementation	1
Engine Rebuilds		Ready for Implementation	3-Expensive, but maintenance and performance benefits exceed cost.
Smaller Fuel Injectors	3-5%	Requires Testing	3-Careful testing of effect of smaller injectors on MPG.
Radial Tires (highway vehicles only)	3-6%	Ready for Implementation	2-Can only be done if highway service vehicles can be identified.
Higher Temperature Thermostats		Requires Testing	2-Monitor results in small number of vehicles before widespread implementation.
Throttle Delays		Ready for Implementation	1
OPERATIONS STRATEGIES			
* Improved Driving Habits	2-10%	Ready for Implementation	2-Instruction, motivation and recognition needed for drivers.
Use of No. 2 Diesel Fuel	1-3%	Ready for Implementation	1-May require blending with No. 1 diesel in cold months.

*Highly recommended for all transit systems

Measure	Estimated % Savings (if available)	Ready for Implementation or Requires Testing	Ease of Implementation 1-Easy; 2-Moderate; 3-More Difficult
Improved Fueling Practices		Ready for Implementation	1
Reduced Idling At Bus Garage		Ready for Implementation	2-Requires monitoring at-garage behavior.
MPG Improvements Through Planning		Ready for Implementation	3-Requires careful analysis and/or negotiation with local and state governments.

PROCUREMENT STRATEGIES

Air Streamlining		Ready for Implementation	1
Temperature Sensitive Fans	2-3%	Ready for Implementation	2-Cost. Increased maintenance problems.
* Turbocharged Engines	6-12%	Ready for Implementation	2-Cost.
Reduced Vehicle Weight	Reduction of 1000 lbs. saves 2%	Ready for Implementation	2-Must maintain crash worthiness.
Evaporative Cooling		Under Development	3-Not yet available.

*Highly recommended for all transit systems.

Note: The percentage savings of these measures are not always additive.

TABLE OF CONTENTS

		Page
Chapter 1	INTRODUCTION	1
Chapter 2	DEVELOPING A FUEL-CONSERVATION PROGRAM	2
	Measuring Current Patterns and Establishing A Baseline	2
	Collecting the data	2
	Using the data	2
	Testing Fuel-Conservation Techniques	3
	Organizing The Fuel-Conservation Program	4
	Segregating The Fleet By Type of Service	5
	Cost-Effectiveness	6
Chapter 3	MAINTENANCE AND EQUIPMENT STRATEGIES	7
	Maintenance Policies and Procedures	7
	Tune-ups	7
	Scheduling tune-ups	7
	Mileage based tune-ups	8
	Performance-based tune-ups	8
	Assigning responsibility for tune-ups	9
	Idling speed	9
	Tire pressure	9
	Manometer air-filter checks	10
	Engine rebuilds	11
	New lubricants	11
	Equipment	11
	Fuel injectors	11
	Radial tires	12
	Cautions	14
	Higher-temperature thermostats	14
	Throttle delays	14
	Summary of Recommended Maintenance and Equipment Strategies	15
Chapter 4	OPERATIONS STRATEGIES	16
	Driving	16
	Driver training and motivation	16
	Setting goals	16
	Recognition	17
	Driving Techniques	17
	Idling	17
	Smooth starts and stops	18
	Defensive driving	18
	Other driving techniques	18

TABLE OF CONTENTS (continued)

		Page
Chapter 4	OPERATIONS STRATEGIES (continued)	
	Additional Operating Strategies	18
	No. 1 versus No. 2 diesel	18
	Fueling	19
	Eliminate unnecessary idling at bases	19
	Segregate the fleet by function	20
	Increase average bus speed through planning	20
	Summary of Recommended Operations Strategies	20
Chapter 5	PROCUREMENT	21
	Air-streamlining	21
	Temperature-sensitive fans	21
	Cautions	22
	Turbocharged engines	22
	Reduced vehicle weight	23
	Evaporative-cooling technology	23
	Summary of Recommended Procurement Strategies	23
Chapter 6	CONCLUSION	24
	Summary of Fuel-Conservation Measures	24
	Maintenance and Equipment Strategies	24
	Operations Strategies	25
	Procurement Strategies	25
APPENDIX A	ESTIMATED FUEL SAVINGS	26
	Radial Tires	26
	Temperature-sensitive Fans	27
	Tire Pressure	27
	Tune-ups	28
REFERENCES		29

Chapter 1

INTRODUCTION

Controlling fuel costs has become a key objective for transit managers throughout the United States. As recently as 1978, before the nation's second energy crisis, diesel fuel cost about 30 cents per gallon, and fuel costs represented a modest proportion of the typical transit operating budget. Today, however, with diesel costing nearly $1 per gallon, fuel costs are a major budget item, averaging 7 to 10 percent of the typical transit operating budget. For many agencies, fuel is the largest operating expense after wages and salaries.

This manual is a practical guide to reducing fuel consumption in the transit revenue fleet. It is written for maintenance managers and planners responsible for maintenance and cost-efficiency issues. The manual describes concrete steps that can be taken at relatively low cost to yield modest, yet significant, fuel and budget savings. The savings will not be dramatic, but the actions identified here can make a valuable difference, particularly in today's world of tight budgets.

The manual is divided into four sections. Chapter 2 provides some key first steps and general guidelines for developing an uncomplicated fuel-conservation program. Chapter 3 discusses maintenance procedures and equipment changes that can improve the fuel efficiency of the existing fleet. Chapter 4 discusses operational techniques, with an emphasis on driver training and driving techniques, that can increase vehicle miles per gallon (MPG). Chapter 5 considers issues of procurement, such as what to specify when purchasing new coaches to maximize MPG.

While the primary focus of this report is fuel conservation, managers who implement the steps described here will find additional returns, including better coach performance, fewer breakdowns, lower accident rates and increased rider comfort. Not all of the suggestions will be appropriate for every transit system, but each system should be able to achieve fuel savings of 5 to 20 percent by following appropriate actions included in this report. That means reducing the total operating budget by 0.4 to 2 percent--savings that everyone can use in these difficult times.

Chapter 2

DEVELOPING A FUEL-CONSERVATION PROGRAM

Measuring Current Patterns and Establishing A Baseline

While it is possible to implement many of the fuel-conservation steps discussed in this manual without ever measuring the fuel efficiency of the fleet, it is recommended that a program begin by measuring the miles per gallon (MPG) attained by each coach in the fleet. This calculation—based on the total number of miles a coach travels divided by the number of gallons consumed by the coach—will provide a baseline from which the success of a fuel-conservation program can be measured. While the data must be collected daily, it is sufficient to compile and review it on a monthly basis.

$$\text{MPG} = \frac{\text{No. of coach miles traveled}}{\text{No. of coach gallons consumed}}$$

Collecting the data. Gallons of fuel consumed must be recorded at the time each coach is filled, and this information must be maintained separately for each coach. While these data can be recorded manually, greater accuracy will be achieved if the number of gallons consumed is recorded automatically at the pump.

Miles traveled per coach can most easily and accurately be measured with a hubodometer. The hubodometer reading can be recorded by the person who fuels the coach each day. The fuel consumption and mileage data can then be added to manual records by clerical staff or entered into a computer, depending on the resources available to each transit agency.

If the buses are not equipped with a hubodometer and there is no budget to buy them at $40 apiece, then a more complicated record-keeping procedure must be followed. A data base must be established with the length (in miles) of each bus route and each run; that is, the total distance traveled from the time a coach leaves the garage until it returns. Each day, personnel at the garage must record the run served by each coach as well as all unanticipated changes, such as breakdowns and reroutes. This record-keeping system is very difficult to maintain manually and is more suitable to the use of a computer. When each day's runs and unanticipated changes are entered into a computer, the computer can translate the data into miles traveled for each coach.

Using the data. This data on fuel consumption and miles traveled can be maintained in several ways. Until recently, smaller agencies have generally relied on clerical staff to record and manipulate the data. While this may seem to be the simplest method, it can actually require quite a bit of staff time to maintain the records, and there is a resulting tendency not to use the data as much as might be used were less staff time required. There is also an increased risk of error in the data because so much manual calculation is involved.

The approach generally taken by larger systems has been to record the data manually at the bus garage and then enter it into a mainframe computer. Because the data

is stored on a large computer, this approach offers the greatest potential for manipulating the data to provide useful information. There are, however, certain drawbacks. This approach requires specialized staff; that is, a systems analyst, which many smaller systems can't afford. In addition, it restricts the maintenance manager or supervisor's access to the data by forcing him or her to ask the analyst for the information.

A third approach to maintaining data is just now evolving as microcomputers and specialized software packages are being adapted for use in the transit industry. Extensive information on energy-management information systems and fuel-control systems will be provided in future reports. Microcomputers offer valuable assistance to managers and supervisors who need to maintain and have easy access to basic data on maintenance and fuel consumption. The use of microcomputers at the bus garage will allow the fuel consumption and mileage data to be entered directly into a computer at the fueling site. This will simplify the data-entry process, enable managers and their staffs to have direct access to the data, and greatly increase their ability to use it. Further, the use of microcomputers will eliminate the lag between data entry and data reporting. As soon as data is entered, it can be called up on a screen. Several transit agencies have already installed fuel management systems, including Boston's Massachusetts Bay Transportation Authority (MBTA); Detroit's South-East Michigan Transportation Authority (SEMTA); Houston's Metro and Washington's Metropolitan Area Transportation Authority (WMATA).

Testing Fuel-Conservation Techniques

All of the ideas discussed in this manual have saved fuel for some transit agency or trucking company, but not all of them will benefit a particular transit system. Each system should select ideas and test them to determine the effectiveness for its fleet. It is important that each test be designed to yield reliable data.

There are two basic kinds of tests: laboratory and road. Laboratory tests are typically conducted with a dynomometer; in this environment, most variables can be controlled, and the effect of the technique in question can be determined. If an agency does not own a dynomometer, it is possible to contract for the use of one, possibly with a larger diesel-vehicle maintenance firm. In some cases, laboratory tests will yield significantly different results than are experienced with coaches in service, and road tests will be required. Some techniques simply cannot be tested with a dynomometer and will have to be road-tested.

To conduct a reliable road test, as many variables as possible must be controlled to isolate the effect of the technique being tested. Otherwise, certain factors may have dramatic effects on a coach's fuel efficiency and skew the test results. An individual driver's style, the passenger load, whether the bus is operated in the city or suburban service, the tightness of the schedule and traffic congestion can all affect vehicle MPG significantly.

To test the effect of radial tires, for example, as many of these factors as possible should be kept constant. Assign the same driver to the same coach every day of the test period, and make sure each driver and coach makes the same run every day. Select five coaches (or 10, if the system has more than 200 coaches) and run them on standard bias-ply tires for two weeks followed by two weeks on radial tires. Comparison of vehicle MPG for the first two weeks to the second two weeks, gives a fairly reliable gauge of the change in fuel efficiency caused by the radial tires—if the other factors have been kept constant throughout the test.

ROAD TESTS

- Keep other variables constant
- Use same driver on same coach every day of test period

Organizing The Fuel-Conservation Program

A fuel-conservation program should not be a complicated one with matrices and numerous committees. Indeed, one of the attractions of a fuel-conservation program is that much of it consists of relatively simple steps that can be taken without exhaustive studies or difficult implementation decisions. A transit agency should begin its fuel-conservation program by setting a realistic percentage goal for fuel-economy improvement, such as a 10 percent gain in fleet MPG. Then, start with just two or three of the measures discussed here. More than that and the effort could lose its focus and become too difficult to implement.

The approach a system takes in organizing a fuel-conservation program will depend in part on the types of techniques it chooses to implement. The fuel-conservation techniques discussed in this manual fall into two categories: (1) those that can be implemented with a test and a decision, such as installation of new equipment; and (2) those that require regular action on the part of front-line staff, such as changed routine maintenance procedures.

If the fuel-saving strategies of the first category is selected, responsibility for the program should probably rest with the managers responsible for assessing alternatives and making decisions. However, if techniques requiring changes in routine procedures are pursued, some sort of broader participation in the organization and implementation phases is recommended. Experience shows that if the workers ultimately responsible for carrying out a program are involved in its formulation, their commitment to the program will be much higher.

The decision on how to organize and implement a conservation program is up to each agency, but the following ideas are offered for consideration:

- Hold a meeting of mechanics and drivers to discuss the program and solicit their comments and suggestions on how to make the program successful.

- Create a committee of mechanics, drivers and front-line supervisors, offer them a list of possible actions and ask them to choose the two or three they feel are most appropriate and then ask them to propose how to implement them.

- If an agency has more than one bus garage, set up a committee at each garage, give each a goal of cutting fuel consumption by a certain percentage, such as 5 percent, and ask them to choose the approach. Then, measure the results at each garage, and after a period of time, such as 6 to 12 months, recognize the garage that achieved the greatest savings and each garage that achieved the 5 percent target.

A sound decision requires good information. If front-line staff is included in the decision-making process, make sure they have access to this report and any other fuel-conservation materials that are available.

Once a program is launched, agency management should explain the need for change and every worker made aware of the baseline data--fleet MPG before the program began, stated goals and progress towards those goals. Most people require motivation to change, and many conservation programs fail because they do not adequately motivate the workers responsible for implementing them. It is not enough to issue occasional exhortations to be more efficient. Front-line workers--drivers and maintenance personnel—should be given a clear understanding of where things stand, what the goal is ("Last March, we averaged 3.9 MPG; this March, we want to top 4.1 MPG"), and how it is to be achieved ("With the following three changes in how we operate....").

Segregating The Fleet By Type Of Service

The trucking industry has significantly increased its average miles per gallon, with some firms experiencing gains of more than 25 percent. Truckers have adopted a number of techniques for reducing fuel consumption, many of which may be useful to the transit industry. Some of the truckers' fuel-conserving techniques, however, are not applicable to city transit service and will only be useful to coaches engaged in substantial highway travel. This raises an important issue for transit managers concerned with reducing their fuel budgets.

Many transit systems now provide suburban service, which involves substantial highway travel. There are, however, very few systems that have designated or identified a set of coaches to be used exclusively on highway routes. Most systems assign coaches more or less randomly, so that a given coach is as likely to be in city traffic as on the open road.

If an agency can designate a set of coaches to be used consistently for highway travel, it will be possible to implement some of the energy-saving measures used by the trucking industry—with substantial improvements in fuel efficiency for those coaches. Whereas overall fleet efficiency may increase by about 10 percent as a result of the measures discussed in this manual, the highway fleet can double that efficiency. If one-fifth of a typical transit fleet is used exclusively on the highway, total fuel savings can be increased from 10 to 12 percent.

When asked about the idea of designating a group of highway coaches, many transit managers say it is not practical. They say that lane parking at the garages, along with other factors, make it too complicated to maintain a distinct group of highway service vehicles. Most transit agencies, however, already segregate their fleets according to several criteria. Certain runs must have lift-equipped coaches and others must have articulated coaches. It, therefore, is possible to decide that a certain coach type will be reserved for highway travel.

Some transit systems have decided that cost savings make it worth the effort and do identify specific coaches for highway use. Among the systems that have successfully used designated coaches are Denver's Regional Transportation District (RTD), Boston's MBTA, and Golden Gate Transit of the San Francisco Bay area. Managers at these systems have found that certain coaches are better suited to highway service, while others are better suited for city travel. They either designate one of their garages or one type of coach as providing highway service. In Denver, managers ordered a set of coaches specifically for highway service. Those coaches get 5 to 6 miles per gallon, which is well above the national average coach MPG.

Cost-Effectiveness

Reducing fuel consumption is ultimately a budget-cutting tool. Measures that would impose substantial costs to achieve modest fuel savings, therefore, are not cost-effective for the transit-system manager. Whenever possible, the discussion of fuel-saving measures will include methods for evaluating the cost-effectiveness of those measures for a transit system.

According to the federal Urban Mass Transit Administration's compilation of Section 15 reporting, the average transit coach travels 41,291 miles a year and gets 3.66 miles per gallon. This means that each coach uses 11,282 gallons of fuel per year. Assuming each gallon costs 90 cents, fuel will cost $10,154 per coach per year. At this rate, a 1-percent increase in average vehicle MPG would save $102 per coach per year. A 10-percent improvement would save $1,015 per coach per year. For those energy-saving measures that create an ongoing expense, such as more frequent tune-ups, the annual cost can be compared to the annual fuel/dollar savings. For those methods that involve a one-time cost, such as the purchase of new equipment, system management must consider the payback period in determining their cost-effectiveness. The payback period is the length of time something must be used before total savings equals initial costs. For example, if a new piece of equipment costs $100 and its use saves $50 per year, then the payback period is two years. In general, energy-saving investments are considered cost-effective if the payback period is five years or less. To be conservative, an agency should consider only those measures with a payback period of three years or less. This assures a quick return on investment.

POTENTIAL FUEL SAVINGS

41,291 miles/year (nat'l avg) ÷ 3.66 MPG (nat'l avg) = 11,282 gallons/year
11,282 gallons × $0.90 = $10,154/year
1% savings = $101.54 per coach per year
10% savings = $1015.40 per coach per year

Chapter 3

MAINTENANCE AND EQUIPMENT STRATEGIES

Changes in maintenance policies and in standard equipment can have a significant effect on fleet fuel efficiency. The maintenance changes discussed in this manual tend to be labor intensive and will require behavior changes on the part of personnel. They also tend to be lower cost items than the equipment changes discussed here. The equipment changes represent industry advances--new products that are more efficient than their predecessors.

Maintenance Policies and Procedures

Tune-ups. A poorly tuned coach burns fuel inefficiently, resulting in lower miles per gallon, excessive smoke, and lower power for the coach. According to industry estimates, a well-tuned coach can average up to 4-percent miles per gallon more than a poorly tuned one. Based on standard figures of 41,291 miles and 11,282 gallons of fuel per coach per year, this means an aggressive tune-up program reduces annual fuel costs by as much as $406 per coach.

TUNE-UP SAVINGS

41,291 miles ÷ 3.66 MPG = 11,282 gallons
11,282 gallons × $0.90 = $10,154/year
4% savings = $406 per coach per year

The cost of an aggressive tune-up program will vary, but it should not require more than one tune-up per coach per year. Assuming an average labor cost of $16 per hour, including benefits, and an average 2.5 hours per tune-up, tune-ups will cost $40 per coach per year. Compare this with the potential fuel savings of $406 a year. On the other hand, it is important to remember that a tune-up is not the solution to all low-MPG problems. Other possible causes of low MPG should be considered before deciding to tune-up a coach.

Scheduling tune-ups. The old-style transit tune-up program waits for a blatant problem to occur before taking action. Put simply, buses are left alone until either the driver complains that the bus has no power or someone notices excessive smoke in the exhaust. At that point, the coach is brought in and tuned up. Relying on these crude performance indicators means that buses can run for thousands of miles while burning excessive amounts of fuel as long as they do not smoke or show an appreciable drop in power. This can cost hundreds of dollars per coach in wasted fuel.

Mileage based tune-ups. An aggressive tune-up program can be based either on mileage or performance. A mileage-based tune-up program would require tune-ups every "X-thousand" miles. Each system must determine the appropriate figure based on experience with its fleet. Conversations with maintenance managers using the mileage-based system revealed that most of them set a trigger level of between 50,000 and 60,000 miles for a tune-up. Some base their figure on the manufacturer's warranty, others on their gut feeling for the intervals at which the buses tend to need tune-ups. The trigger level can vary considerably, however, depending on the type of engine, the type of service provided by the coach and the weather, among other things.

To determine the optimal trigger level for a fleet, select a group of 10 coaches and monitor their performance closely. How many miles do they travel after a tune-up, on the average, before the MPG begins to drop below the fleet average? Use that average mileage as the trigger level. Once the trigger level is determined monitor the miles traveled by each coach and make it a firm policy that each one reaching the trigger level receive a tune-up promptly.

Performance-based tune-ups. Seattle Metro has recently launched a performance-based tune-up program at one of its garages. This program represents a step forward because it is directly tied to fuel efficiency, which is the primary reason for tuning up vehicles. Vehicle fuel efficiency is monitored, and when a coach's MPG drops below acceptable levels, the coach is sent in for a tune-up. The advantage of a performance-based system is that only those coaches that need a tune-up get it and they are tuned up right away. Under this system, if a coach can travel 100,000 miles before its performance deteriorates, then it will not be tuned up until it reaches 100,000 miles, thus avoiding unnecessary tune-ups. If another coach needs tuning after 25,000 miles, then it will be tuned up at 25,000 miles and excess fuel consumption will be stopped quickly rather than allowing the waste to continue until the coach has reached a designated mileage level.

Of course, a tune-up program based on performance data requires careful attention and sound judgment from maintenance supervisor and foremen. It also requires a good maintenance tracking system so that a coach's maintenance history is readily available to the maintenance personnel evaluating problems. A low MPG for a single month does not mean absolutely that a coach needs a tune-up; there may be other reasons for low performance. If a coach's MPG rating for the previous month was low, the records should be checked to determine the last time the coach was tuned up. If the performance is a sudden change, there might be another explanation for it. If it has been tuned recently--within the previous six months—check the coach to see what else might require maintenance. Some other possibilities should also be considered, such as air-intake restrictions, clogged fuel filters or fouled injectors.

PERFORMANCE-BASED TUNE-UP PROGRAM

- Monitor coach MPG
- Schedule tune-ups on basis of coach MPG
- Consider other possible explanations for low MPG
- Develop good maintenance tracking program
- Set trigger level above current fleet average

If a performance-based tune-up program is adopted, it will be necessary to experiment to determine the correct trigger level. Start with a level slightly above the coaches current average. If the average is 3.8 MPG for example, choose 4.0 MPG as a starting point. If not tuning the coaches very often, then raise the trigger to 4.1 MPG. Remember, if the fleet averages 4.1 instead of 4.0, fuel consumption is reduced by 2.5 percent—a tremendous savings. Keep raising the trigger until a point is reached where the buses are being tuned too often. At that point, the trigger should be reduced by one-tenth of a mile per gallon, a system developed for tracking vehicle MPG closely and a firm policy established of tuning coaches when their MPG drops below the newly determined level.

If the different types of coaches in a fleet have significantly different average MPG levels, trigger levels for each type may need to be set. The same process for each coach type should be followed, setting an initial trigger level above the current average and then adjusting it until it can give an optimal MPG.

The manager must be the judge of how often is too often for tuning coaches. Every increase of 0.1 in the average MPG represents about a 2.5 percent gain in fuel efficiency, which is a savings of more than $250 per coach. Since even two tune-ups per year would cost $80 per coach, the value of an aggressive tune-up program is substantial. The process of determining optimal trigger levels will take some time because of the need to observe the results at each level. And, because it is not unusual for a fleet's MPG rating to change significantly from winter to summer, the trigger level used in July should be different than the level used in January.

Assigning responsibility for tune-ups. Even large transit systems tend to operate garages of 200 to 250 coaches each. On this basis, an aggressive tune-up program requires less than one tune-up per day. Preventive maintenance, including tune-ups, is often neglected because of breakdowns and other unanticipated problems. To avoid this neglect, two mechanics at each garage should be designated as the tune-up specialist and assigned the responsibility for performing all tune-ups at the garage. This approach has two merits: (1) it ensures that all buses are tuned up in the same general style, and (2) by designating responsibility to specific mechanics, it is less likely that tune-ups will be neglected because of crisis maintenance.

Idling speed. When tune-ups are done, attention should be given to the idling speed. If a coach's idle speed is set too high, it will waste considerable amounts of fuel. European bus manufacturers are experimenting with super-low idling speeds. Information on these tests should be available within a year or two.

Tire Pressure. The friction between tires and the road reduces vehicle MPG. The manufacturer's recommended tire pressure should minimize friction and optimize MPG. Underinflated tires can cause a significant decline in fuel efficiency, because friction increases as tire pressure declines and the bus engine must work harder to move the tire along the road, thereby reducing vehicle MPG. According to the federally sponsored Voluntary Truck and Bus Fuel Conservation Program, a vehicle's fuel efficiency will drop 1 percent for every two pounds per square inch (psi) of pressure below the recommended amount.

The old-fashioned approach to checking tire pressure, called thumping, consists of hitting the tire. Thumping only indicates that a tire is flat or grossly underinflated. It is a totally unreliable indicator of an underinflated tire. When some transit systems first made a commitment to keep tire pressure at recommended levels, a number of coaches were discovered with tires underinflated by 10 to 15 pounds.

Establishing a serious effort to maintain tire pressure is not difficult. First, ranges for acceptable tire pressure should be eliminated, and the maximum recommended pressure used as a standard. For example, if the manufacturer recommends pressure of 95 to 100 psi, then the standard should be set at 100 psi. If transit systems have a tire contract, arrangements should be made for weekly tire-pressure checks as part of the service contract. If not, the responsibility for checking tire-pressure weekly should be assigned to someone on the maintenance staff and pressure checks made a standard part of routine maintenance inspections. When a goal of maintaining appropriate tire pressure is established, only small deviations from the standard should be allowed. Tire pressure at 5 psi, or even 3 psi, below the recommended level should not be acceptable. It should be a rule that any tire falling below the recommended level by 3 psi or more be inflated immediately.

Several agencies have gone to extra lengths to facilitate correct tire-pressure maintenance. Spokane Transit in Washington state keeps air hoses throughout the bus garage so that any coach with low tire pressure is always within easy reach of an air supply. Sacramento Transit in California has purchased portable air compressors so that tire pressure can be corrected on the spot. In addition to saving fuel, a firm policy on tire pressure should also prolong tire life and reduce tire replacement costs.

TIRE PRESSURE

- Check it weekly
- Fill tires if they are more than 3 psi below recommended level

Manometer air-filter checks. Air filters prevent dirt particles from entering the engine while allowing air to enter and mix with the fuel. With use, air filters become dirty and must be replaced. The conventional approach to maintaining air filters is to replace them every so many miles, such as every 20,000 miles. This approach has two significant drawbacks that cost money. While the average air filter may need to be replaced at 24,000 miles, some filters actually need replacement sooner, while others easily last twice as long as the average. If an air filter is thrown out before it is dirty, then money is being wasted. If an air filter is still used after it is too dirty to allow sufficient air flow, fuel is being wasted and, therefore, money is wasted.

Some transit systems have recently purchased manometers, which measure the air flow through an air filter. A manometer test will show clearly whether the air filter is allowing sufficient air to enter cylinders to provide efficient burning of fuel. By using a manometer to test air filters as part of routine inspection, efficient use of the filters and fuel can be ensured. Manometers cost less than $100 and quickly earn back their cost in prolonged air-filter life and improved fuel efficiency. As with the MPG-based tune-up program, this device ensures that corrective maintenance is done promptly when needed but that unnecessary maintenance is not. Seattle Metro estimates that it has extended the average air-filter life by 50 percent with the use of manometers.

Engine rebuilds. A number of transit systems have improved fuel efficiency and increased the number of miles between breakdowns by implementing aggressive engine-rebuilding programs. Maintenance managers generally report that the average coach runs satisfactorily for 250,000 to 300,000 miles, after which performance begins to deteriorate significantly. Fuel efficiency declines, and maintenance problems become much more frequent.

In the past, many transit systems limped along with their aging fleet and simply struggled to keep up with the increasing number of breakdowns and maintenance problems. Preventive maintenance programs were given limited attention as maintenance crews struggled to handle crises. Recently, however, some systems have adopted firm policies of rebuilding all engines every 250,000 to 300,000 miles. Tri-Met in Portland, Oregon, and Pierce County Public Transportation Benefit Area (PTBA) in Washington state are among the transit agencies that have implemented major engine-rebuilding programs. Their maintenance managers report dramatic improvements in coach performance, including significant increases in coach MPG. Since engine rebuilds are expensive, they certainly cannot be justified economically strictly on the basis of improved fuel efficiency. Rather, improved fuel efficiency is a benefit in addition to significant reduction in vehicle maintenance costs and improvement in coach performance.

New lubricants. In recent years, a number of companies have introduced engine and chassis lubricants that they claim will significantly reduce friction and increase the fuel efficiency of cars, buses and trucks. While these products offer the potential for improved vehicle performance and fuel efficiency, transit systems should approach their use cautiously. Many agencies have found that the promised gains for some products greatly exceed on-the-road performance. In addition, some users have expressed concern over the possibility of increased engine wear, which could more than outweigh the savings achieved in reduced fuel consumption.

Careful testing should be done before any full-scale implementation of a new product. Testing guidelines discussed earlier in this manual should be followed, keeping constant as many variables as possible. This includes controlling for the influences of driving style, types of service, traffic congestion, frequency of stops and other items discussed in Chapter 1. Because of possible engine damage, careful measurements of the engine parts before and after a test period should be taken to be sure excessive engine wear does not result from use of the new lubricant. Even after positive test results and implementation of the new product, monitoring should be continued.

Equipment

Fuel injectors. Fuel injectors eliminate the need for a carburetor by metering the flow of fuel into the engine and injecting it directly into the cylinder. An incorrect fuel injector size can waste fuel. If the injector openings are too large, then the engine will be fed more fuel than it can handle efficiently while the bus accelerates. If the openings are too small, the bus will be underpowered and take too long to move out of the lower, less efficient gears.

It is not possible to say that one injector opening is the best for all buses. The appropriate size of the opening depends on the demands placed on the bus, the engine size and the power required to meet those demands. For example, if a bus usually climbs steep hills, larger injector openings may be needed to power the bus in the lower gears. By contrast, if a bus spends much of its time on the freeway, smaller openings may provide sufficient power and reduce fuel consumption.

The best way to select an optimal injector size is through simple experimentation during road tests. Twelve recently tuned coaches should be assigned specific drivers for the test period. Three coaches of the type best suited to highway travel to be used exclusively in highway service should be assigned, and three coaches of the type best suited to city travel assigned to be used in city service exclusively. The other six coaches should be assigned to routes in the usual manner. The MPG for each coach should be monitored for two weeks. Smaller injectors should be installed in the three highway-service coaches and half of the all-service coaches, and larger injectors should be installed in the three city-service coaches and the other half of the all-service coaches. The MPG should be monitored for another two weeks, and the results compared to the first two weeks.

If the all-service coaches, equipped with either larger or smaller injectors, show higher MPG during the second period, then it can be concluded that the entire fleet could achieve higher MPG by switching to that new size. If the highway-only (or city-only) coaches show improved MPG during the second two-week period, then it can be concluded that smaller (or larger) injectors could save fuel if the fleet is segregated into highway-service and city-service coaches.

Injectors, therefore, are a case in which segregating a fleet can create additional fuel-saving opportunities. Over-the-road vehicles can run efficiently with smaller-sized injectors, thereby increasing MPG and still providing enough power. Some agencies find that smaller injectors work best on highway service coaches, while their current size is best for city service.

Most transit systems use the C-60 injector. Some systems, including Golden Gate Transit, and those in Sacramento, Wichita and Boston, have switched to the smaller 55s. These agencies feel the smaller injectors provide sufficient power for their coaches. It is important to note that most of these systems serve relatively flat areas.

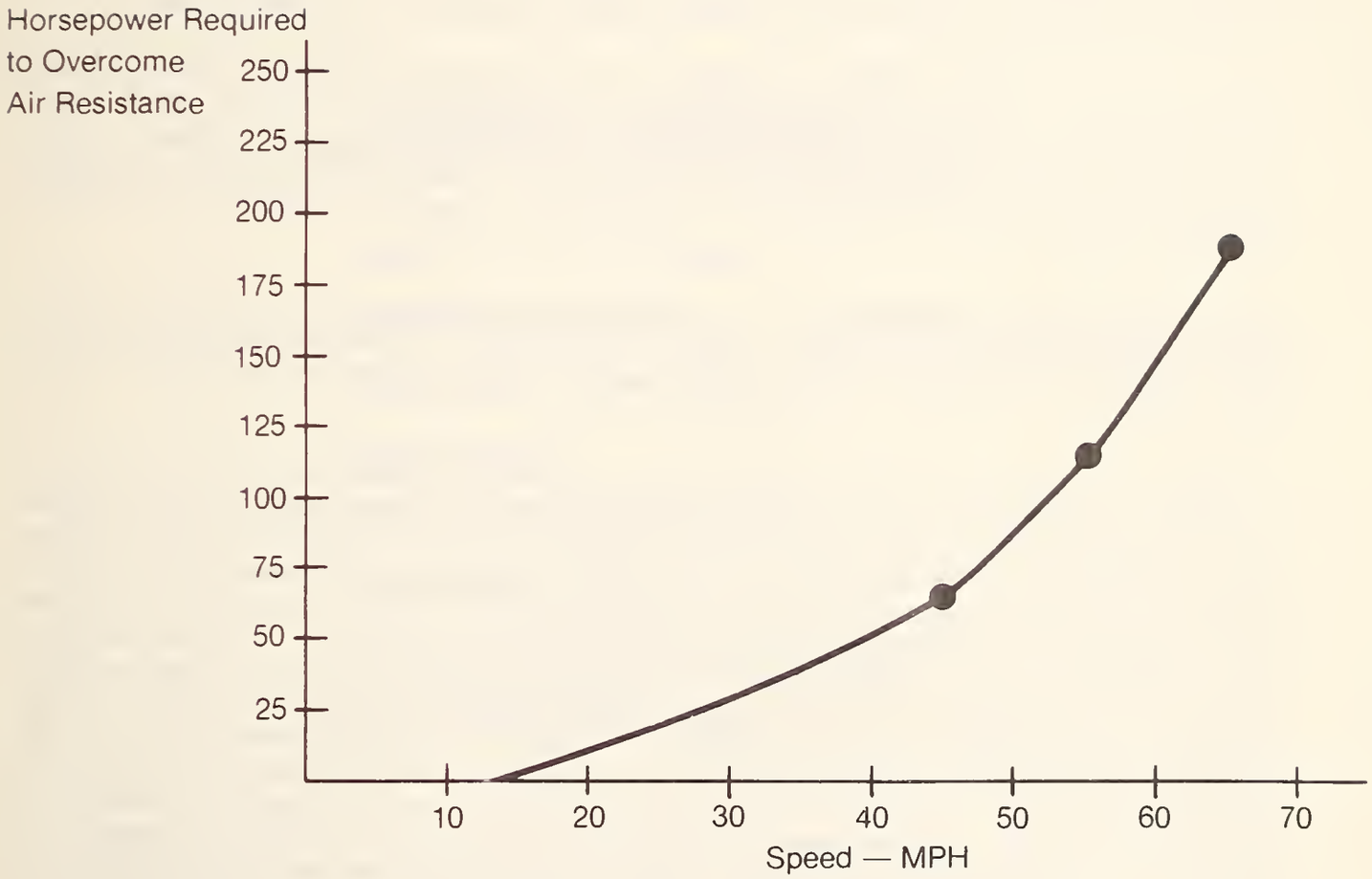
Radial tires. Friction between the tires and the road is a major factor in reducing the fuel efficiency of vehicles. Because of their design, radial tires encounter considerably less friction than standard bias-ply tires. The over-the-road trucking industry has switched almost entirely to radial tires, resulting in fuel savings estimated at 6 percent.

Radial tires are of more limited value to transit systems because of the nature of their travel, but in certain cases may yield valuable fuel savings. Radial tires have a greater effect on fuel efficiency at speeds over 35 miles per hour. At lower speeds the difference between radials and bias-ply tires is more modest. Radial tires should be used only for buses operating primarily on the highway with very limited amounts of city service.

Tire selection is another case in which segregating the fleet according to function can yield additional fuel savings. If a group of coaches can be identified for consistent use on the highways, the fuel economy should improve by 3 to 6 percent, depending on the proportion of highway and the average highway speed for those coaches.

Another advantage of radial tires is their longer life, due to the fact they can be recapped more times than bias-ply tires. The purchase price of radials is higher than bias-ply, but their longer life and better fuel economy should result in a lower cost per mile for the life of the tire.

EFFECTS OF AIR RESISTANCE



Cautions. Radial tires should not be used for buses traveling primarily in city traffic. The construction of a radial tire results in a weaker sidewall than that of a bias-ply tire, which means a radial is more easily damaged by rubbing against curbs. Since city travel inevitably involves grazing curbs, equipping city-service coaches with radials could result in an unacceptably short tire life.

A second problem with radials on city-service coaches is their susceptibility to heat damage. High temperatures can cause irreversible damage to radial tires, which are more sensitive to heat than bias-ply tires. Because city buses brake so often, they generate high heat levels in bus wheels, which threatens to ruin radial tires.

One parting word about radials. Because they are designed differently than bias-ply tires, they have a different feel to drivers. Initially, drivers may complain about them and say they are having a difficult time controlling the bus. Experience shows that drivers adjust to the radial tires in a matter of days or weeks and complaints disappear. Therefore, a brief period of adjustment is needed if radial tires are used on some buses.

Higher-temperature thermostats. In a warm engine, fuel burns more efficiently than in a cold one, and oil moves more freely, providing less resistance and friction. The more complete combustion of fuel in a warmer engine means more BTU's in each gallon of fuel.

It stands to reason that if the temperature of an engine is raised without overheating it, then the efficiency of the engine can be improved. Most buses come equipped with thermostats and alarmostats that activate at 170° or 180° Fahrenheit. Some transit systems, including Denver RTD and Seattle Metro, have switched to thermostats and alarmostats that accept engine temperatures up to 190° F. before activating the cooling system. These higher temperatures should improve oil flow and increase fuel combustion, which should improve vehicle MPG. There are no transit-industry test data to determine the probable fuel savings from changing thermostats. While changing thermostats is likely to result in a smaller gain than some of the other techniques discussed in this manual, it is a relatively simple method that can be implemented easily. The cost of replacing thermostats and alarmostats is about $72 for each coach and involves about 1.25 hours in labor. If this change increases fuel efficiency by 0.44 percent or more, it will be cost-effective and pay for itself in two years or less. The gain is much greater when a temperature-controlled fan is used, and shutters are removed.

The risk of overheating the engine may increase when a higher-temperature thermostat is used. One way of reducing the risk of damage from overheating is to install a higher-pressure radiator cap, which costs only about $2.50. This will raise the internal pressure of the cooling system and, in turn, raise the boiling point of the coolant. A minimum of 9 psi for sea level and 14 psi for 5,000 feet above sea level is recommended.

Throttle delays. Gunning the engine wastes fuel. When flooring the accelerator while pulling out of a stop, a driver is supplying more fuel to the engine than it can handle. The result is wasted fuel and excessive smoking.

To avoid these problems, most new buses come equipped with a throttle-delay valve or some other device restricting the amount of fuel that can be injected into the engine during the first few seconds of acceleration. Thus, even if the accelerator is pushed to the floor, a corresponding amount of fuel is not released.

Some transit agencies have disengaged these throttle-delays to allow more fuel into the engine and provide a greater surge of acceleration. While there may be a very slight increase in the power of a bus pulling out of a stop, there will be a much greater increase in exhaust and wasted fuel. Agencies with nonfunctioning throttle-delays should replace them. The improvements in vehicle exhaust and fuel efficiency should be worth the replacement of a new throttle-delay, which costs about $75. If the fleet includes older coaches that were not equipped with throttle delays, installation of these devices is recommended.

SUMMARY OF RECOMMENDED MAINTENANCE AND EQUIPMENT STRATEGIES

Aggressive Tune-up Program

Tire-pressure Maintenance

Manometer Air-filter Checks

Engine Rebuilds

Appropriate Fuel Injectors

Use of Radial Tires

Use of Higher-temperature Thermostats

Use of Throttle-delay Valves

Chapter 4

OPERATIONS STRATEGIES

Driving

Many energy-conservation specialists claim that coach operators can be the best source of fuel savings. Estimates of the potential fuel savings from energy-efficient driving range as high as 20 percent. In fact, some trucking companies that have launched major fuel-conservation programs aimed at their drivers have achieved savings of more than 25 percent. Every transit system should make fuel-efficient driving one of the key components of its fuel-conservation program. To succeed, however, such a program requires both vigorous training and regular motivation and recognition for the drivers.

Driver training and motivation. The typical bus driver probably knows that the way he or she drives the bus will influence the coach's MPG, but probably does not know just how much of a difference his or her driving can make. Furthermore, many drivers have no idea what the average fleet MPG is nor whether management considers that figure to be good or bad. Finally, the average driver has no idea how his or her own driving rates because there is usually no effective way to measure individual MPG.

It is assumed that drivers do not know how to maximize their vehicle MPG, nor do they recognize that many safe-driving strategies are also energy-saving techniques. Energy-efficient driving techniques should be included in the basic instruction given to new bus drivers. A good training program will tell drivers how to drive in an energy-efficient manner as well as present the statistics that demonstrate fuel-savings potential. By making it clear to drivers the difference they can make, the greater motivation they have to follow their training.

Setting goals. Training, however, is not enough to ensure good driving habits. To realize significant savings from improved driver performance, energy conservation must be established as a major goal for the system and the drivers. Drivers should be made aware of current consumption patterns, such as the average MPG for their garage. And, goals must be articulated clearly, such as increasing fleet MPG from 4 MPG to 4.2 MPG. In this way, drivers may appreciate management's concern and see themselves as part of an overall team effort. Easily understood, quantifiable goals are much more likely to bring about improved driver performance than sporadic, vague exhortations to drive more efficiently.

Golden Gate Transit has designed an aggressive driver-awareness program to involve drivers in a fuel-conservation campaign. Signs--stating the latest fleet MPG figures and specifying targets for the current month--are posted at strategic locations at bus garages. Drivers are issued brochures on fuel-conservation driving techniques, and fuel-efficient driving is stressed during initial training and retraining. Incidentally, the Golden Gate fleet averages more than 5 MPG.

If goals are set, they should be based on monthly targets so that drivers can receive regular feedback on performance. Performance goals should be based on the same month of the previous year; that is, base a goal for March 1984 MPG in comparison to March 1983 MPG. This way the effect of seasonal variation is eliminated, which can range up to 5 percent over the year.

Recognition. Setting goals is the first step in a program to promote fuel-efficient driving. To be successful, however, a program must provide recognition and rewards when goals are reached. In private industry, drivers are often rewarded with bonuses for fuel-efficient driving. This approach is more difficult to implement in the public transit industry, in large part because it is nearly impossible to measure the performance of individual drivers. A complication in evaluating individual drivers is the variation in routes. A hilly, city route, for example, will have lower MPG than a flat, suburban one. It is, therefore, difficult to compare the performance of two drivers on different routes. Nonetheless, some sort of recognition for more fuel-efficient driving is essential, at least on a group basis.

Some ways to recognize achievement are to provide all of the drivers at a garage with coffee and donuts, publish articles in company publications and local newspapers, or award certificates and shoulder patches. What is important is that every driver feel that he will be recognized if he does a good job and that every driver feel part of a team effort.

Driving Techniques

Idling. Idling coaches are major fuel wasters. While idling, a coach gets zero miles per gallon. It is, of course, necessary to idle coaches when they are started in the morning, but even then three to five minutes is usually enough to build up pressure levels. But once minimum pressure levels are attained, a coach will warm up faster if it is moving. Tires are a key element that need to be warmed up. As long as they are cold and less pliable, the coach will run inefficiently. No matter how long an engine idles, the tires do not begin to warm up until the coach is on the road. In addition to wasting fuel, excessive idling can cause engine problems—extended idling causes carbon to build up and clog the injectors.

The only other time idling is necessary is to cool an engine down after the coach has been in service. Then, it is necessary to idle the engine for about three minutes to ensure that the engine will cool down evenly, thereby protecting against damage to the engine. This cool down time is less important if the coach has been in stop-and-go traffic on the way back to the garage.

Many drivers believe they need to idle the engine during layovers to keep it warm, but tests show that an idling engine actually cools down faster than one that has been turned off. Even at below-freezing temperatures, after half an hour an engine that has been turned off is warmer than an idling engine, and after one hour they're at the same temperature. And, as a rule, it takes less fuel to restart an engine than it does to keep the engine running for one minute. However, because three minutes of idling will cool down an engine, a driver with more than four minutes of layover should turn the engine off after three minutes.

Unnecessary idling occurs both at the garage and during layovers in the field. Idling at the garage can be controlled more easily because the bus is in view of other personnel. Unnecessary idling during layovers is a more difficult problem to detect. Many transit systems estimate that 12 to 18 percent of their platform hours are spent on layover. This represents a huge fuel-saving potential if unnecessary idling can be eliminated. But, because layovers usually occur in unsupervised areas, management has little means for enforcing an idling policy. A campaign against wasteful idling, therefore, must rely on motivation rather than on enforcement. The issue of idling should be discussed during basic driver training explaining that a typical diesel engine consumes half a gallon per hour when idling. Periodic bulletins reminding drivers

of the agency's idling policy should be issued, and signs should be placed in prominent locations at the bus garage.

Smooth starts and stops. The driver who barrels to a stop at red lights and bus stops and guns the engine when pulling out of a stop is costing a transit system money and gives passengers an unpleasant ride. Drivers should coast to a stop. This reduces wear on the brakes and the passengers while saving fuel and money. When pulling out of a stop, drivers should accelerate briskly, but steadily. Gunning the bus will waste fuel, as will a hesitant or timid start.

Defensive driving. Defensive driving is primarily a safety measure. By looking down the road, drivers can spot potential problems and either avoid them completely or be prepared to respond to them. This sort of anticipation can greatly reduce the accident rate for a bus system.

Defensive driving also improves fuel efficiency by cutting down on sudden stops and accelerations. Because drivers can slow down in anticipation of potential problems, they can keep their buses rolling at steadier speeds. Stop-and-go driving cuts heavily into mileage efficiency, whereas a steadily moving bus will achieve significantly better MPG.

Other driving techniques. There are other measures that will help drivers achieve greater fuel efficiency. These include:

- **adherence to posted speed limits.**
- **letting up on the gas pedal when traveling downhill.**
- **turning off air conditioning while climbing steep hills.**

Additional Operating Strategies

No. 1 versus No. 2 diesel. Diesel fuel for transit use comes in two grades: No. 1 and No. 2. Diesel No. 1 is similar to jet fuel. It is lighter and has a cleaner burn than No. 2, widely used in trucks. Until recently, most transit systems operated their buses exclusively on No. 1 diesel fuel to minimize exhaust and fumes. However, as rising fuel prices have increased the pressure to reduce fuel costs, many systems have converted to No. 2 diesel, which typically costs 3 to 12 cents per gallon less.

A few transit systems that have experimented with No. 2 diesel have found it produces unacceptable levels of smoke and odor and fouls the injectors. The majority of systems, however, report no exhaust or fouling problems from use of No. 2 diesel. This is due in part to a higher grade No. 2 diesel than was produced in the past. The risk of smoke and fumes from No. 2 diesel can be further reduced by specifying a higher-than-average cetane rating. The cetane rating is an aggregate indicator of fuel quality and is usually 45 for No. 2 diesel. By specifying a cetane rating of 46 or 48, these problems can be avoided.

Of course, cold weather will also make an engine burn fuel less efficiently. Some transit systems, including Minneapolis' Metropolitan Transit Commission and Atlanta's Metropolitan Atlanta Regional Transit Authority (MARTA) have elected to burn No. 2 for most of the year and use No. 1 diesel or a blend of No. 1 and No. 2 during the winter months to avoid problems with smoking or difficult starting. Some systems, including Seattle Metro, use an additive to prevent excessive smoking in coaches using No. 2 diesel.

In addition to price savings, No. 2 diesel has a higher BTU content per gallon--about 7 percent more than No. 1 diesel. Switching from No. 1 to No. 2 should increase vehicle MPG by 1 to 3 percent. The higher BTU content of No. 2 diesel may also make it possible to switch to smaller-sized fuel injectors. The current injector size may be the one best suited for coaches when they are operating on No. 1 diesel, but not if they are operating on No. 2. If the coaches switch to No. 2, consider going to a slightly smaller injector.

Fueling. A common practice used by bus fuelers wastes substantial amounts of diesel fuel. Standard fuel nozzles contain an automatic shutoff valve. Often in fueling, fuel backs up and activates the valve, which stops the flow of fuel well before the tank is full. Because this malfunctioning valve is an inconvenience, some fuelers bypass it completely so it never automatically shuts off. This may solve the immediate problem (at the cost of broken equipment), but it also means that most tanks are overfilled and fuel is spilled. While there are no statistics on the extent of losses due to spillage, the average coach will lose one-eighth of a gallon per day, or 37.5 gallons per year based on 300 fuelings per year, if one-fourth of a gallon is spilled in half the coaches fueled each day.

There are two possible solutions to this problem. One approach is to use a narrower nozzle, which would reduce the rate of fuel flowing into the tank and should reduce, if not eliminate, the problem of premature activation of the shutoff valve. The tradeoff, however, is an increase in the time required to fuel each coach, which will raise the cost of fueling operation.

Another solution is the use of drybreak nozzles--already common in the trucking industry, which claims they eliminate the premature-shutoff problem. A subsequent report will discuss drybreak nozzles as part of a comprehensive fuel-management program.

Eliminate unnecessary idling at garages. Old habits, including practices that waste fuel, die hard. Recent audits of transit systems have shown it is not uncommon for coaches to be left idling for long periods of time while out of service for maintenance or cleaning. This throwback to the days of cheap fuel wastes substantial amounts of fuel and money. An idling coach consumes about half a gallon of fuel, per hour. Extended idling also leaves carbon deposits that impair injectors and can accelerate engine wear.

Since activities at the garage are within the control of management, this wasteful practice can be curtailed. It is a matter of changing habits, which requires that the maintenance manager and garage supervisor take a strong, consistent position on the unacceptability of this practice.

Some transit systems also use substantial amounts of fuel while idling coaches at night during cold winter months. UMTA audits and other field inspections have even found that some systems idle coaches through the night so they will be warm in the morning. A number of systems, including Salt Lake City's Utah Transit Authority (UTA) have instead purchased coaches with block heaters or have retrofitted existing coaches with block heaters. A variety of heaters are available, all of which function by heating either the engine block, the coolant or the oil pan. When a bus is out of service, the heater is plugged into a power source. The heater can be controlled by a timer or by computer to allow only as much operation as needed to keep the engine warm. The use of block heaters requires far less manpower and energy to keep engines warm than do idling coaches. In many cold climates, heated parking garages are used to accomplish the same goal of avoiding nighttime idling in winter months.

Segregate the fleet by function. It is possible to obtain additional fuel savings if coaches can be separated according to function, setting aside those that will be used consistently in highway service. If it is known that a coach will be used primarily on the highway, then it becomes cost-effective to implement additional fuel-saving techniques, such as the use of radial tires, smaller fuel injectors and temperature-sensitive fans. (See Chapter 4.)

Again, it is important to note that most transit systems have already demonstrated that it is possible to segregate coaches for particular functions—using lift-equipped coaches on certain runs, for example, and articulated coaches on others. Some systems even maintain policies of assigning newer coaches to certain routes. These examples show it is indeed possible to identify a set of coaches for highway service and use them regularly in that capacity.

Increase average bus speed through planning. The more smoothly a bus travels--with fewer brakings and accelerations--the better MPG it will achieve. While much of this responsibility rests with the drivers, a transit system can increase fleet MPG by adopting planning strategies that will increase average bus speeds. These include:

- **Exclusive bus lanes on highways and major arterials.**
- **Bus-only curbside lanes and one-way streets in central business districts.**
- **Peak-hour turning and curbside parking restrictions for automobiles in downtown areas.**
- **Bus-activated traffic-control systems.**

All of these planning strategies provide multiple benefits—improved traffic flow for automobiles as well as for buses and savings in vehicle operating time as well as in fuel. Many of the strategies, however, are controversial and require careful negotiations and coordination with appropriate government agencies for them to be successfully implemented and enforced.

SUMMARY OF RECOMMENDED OPERATIONS STRATEGIES

Improved Driving Habits

- **Reduced Idling during Layovers**
- **Smooth Starts and Stops**
- **Defensive Driving**
- **Adherence to Speed Limits**
- **Downhill Coasting**

Use of No. 2 Diesel

Improved Fueling

Reduce Idling at Garages

Traffic-flow Improvements through Planning

Chapter 5

PROCUREMENT

All of the techniques discussed in Chapters 3 and 4 are methods of increasing the fuel efficiency of an existing fleet. Some of the most important fuel-saving decisions, however, will be made when the specifications are prepared for the next bus purchase. This chapter addresses some of the key issues of fuel efficiency to consider when ordering new coaches.

Air-streamlining. For buses traveling in city traffic at low speeds, air resistance is not a significant factor. But as vehicle speed increases, air resistance increases geometrically. In fact, at speeds over 60 MPH air resistance is the singlemost factor reducing MPG. As transit systems provide more and more freeway and suburban service, efficient aerodynamic design to overcome air resistance becomes more important.

In general, the passenger-capacity requirements of buses make it difficult to design a streamlined bus. Still, it seems as if some coaches are designed with almost square front surfaces and so maximize air resistance. If the new coaches may be used in service exceeding 40 mph, then the specifications should include the following:

- **sloped windshields,**
- **rounded corners,**
- **smooth vehicle sides.**

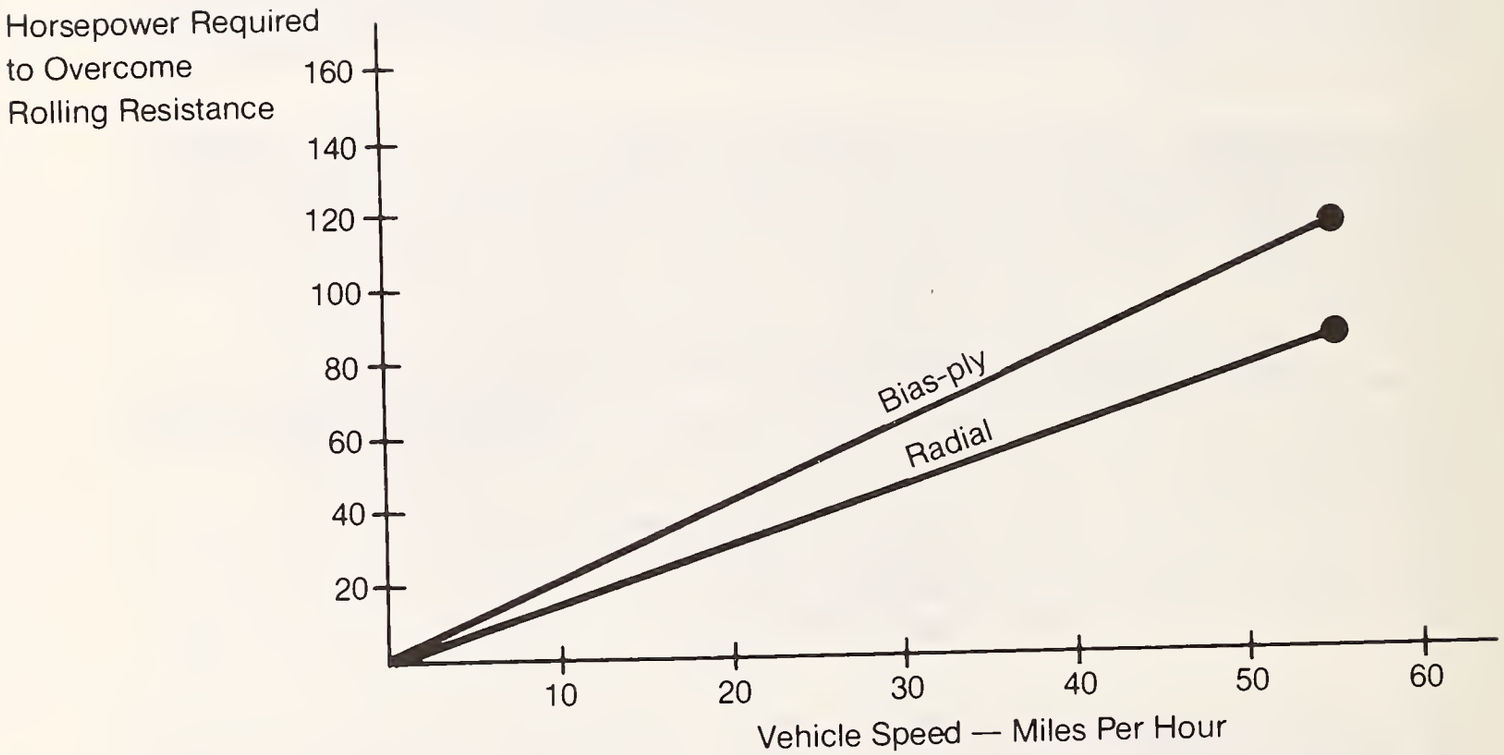
Temperature-sensitive fans. Engine fans require considerable power ranging from 10 to 40 horsepower (hp). Conventional direct-drive fans operate whenever the engine is running, diverting a significant amount of horsepower from bus propulsion. Conventional fans, therefore, impose two burdens on bus fuel-efficiency: (1) they require fuel to be powered; and (2) they necessitate a larger-sized engine--large enough both to turn the fan and to propel the bus.

By contrast, temperature-sensitive fans are activated only when engine temperature rises to a certain level and operate only as long as needed to reduce engine temperature to acceptable levels. Over-the-road truckers have switched to temperature-sensitive fans and found that the fans are in use less than 5 percent of the time. Truckers are not only saving fuel that would have powered the fan the other 95 percent of the time, but they are also able to use smaller, more fuel-efficient engines. Tests with temperature-sensitive fans show fuel savings in trucks averaging 5.5 percent--a dramatic gain.

Coaches in city traffic, of course, will use their fans more than 5 percent of the time, but a system should still be able to achieve significant fuel savings by ordering new buses with temperature-sensitive fans. Even if the fans run half of the time, fuel savings should still run 2 to 3 percent, or $200 to $300 per coach per year. And, an additional benefit is gained--reduced noise pollution from loud diesel-fan noise.

EFFECTS OF ROLLING RESISTANCE

Bias-ply vs. Radial Tires



Cautions. While there are definite advantages to temperature-sensitive fans, there are also certain drawbacks. These fans tend to require more maintenance than direct-drive fans. While the increased maintenance is difficult to quantify, it should definitely be considered an offset to the fuel savings of $300 to $400 per coach per year.

Another alternative to the conventional direct-drive fan is currently being developed. A lightweight, low-speed, direct-drive fan requiring less than 10 hp to operate may be available within a few years. While its lower speed may reduce its cooling power and limit its effectiveness under certain operating conditions, this fan may be an attractive alternative, particularly if it requires less maintenance than temperature-sensitive fans.

Turbocharged engines. Turbocharged engines represent a major advance for diesel engines. Basically, they force extra air into the combustion process, thereby increasing ignition efficiency and generating significantly more horsepower than a conventional diesel engine of the same size. Fuel is also burned more cleanly, resulting in less air pollution.

Though turbocharged engines generally cost a few thousand dollars more than standard engines, the operating savings should compensate for the higher initial cost. Most transit systems are now purchasing turbocharged engines because of their greater power and efficiency.

Reduced vehicle weight. The amount of fuel required to power a vehicle increases with the weight of the load. Weight causes the biggest drain on the fuel efficiency of coaches engaged in stop-and-go travel. Tests of the Advanced Design Bus showed that a weight reduction of 1,000 pounds could improve MPG by 2 percent. Despite the growing concern for fuel economy, buses today are significantly heavier and achieve lower mileage than buses 10 years ago. New coaches should be ordered with lighter-weight materials and fewer pieces of heavy add-on equipment, as long as the crash resistance and structural integrity can be maintained.

Evaporative-cooling technology. As stated before, air conditioning is a fuel-consuming necessity during hot summer months. Estimates vary, but it is safe to say that using the air-conditioning system reduces fuel efficiency by 0.4 to 1 MPG. In addition, air-conditioning systems are a major problem for many maintenance departments. Obviously, an alternative way to cool bus interiors would be very desirable.

Denver RTD is currently experimenting with evaporative-cooling systems--the technology behind the design of the first generation of refrigerators. It is possible that this very old technology--based on the principle that evaporating water takes heat with it--could be put to use in cooling buses. By retrofitting coaches with a high-powered ventilation unit and new evaporative-cooling equipment, Denver RTD has been able to reduce coach temperatures by as much as 25°F. Though fuel-savings statistics are not yet available, this new cooling system clearly offers the possibility of improving vehicle MPG while eliminating a major maintenance expense. Reports on Denver RTD's work with evaporative-cooling technology should be available soon through UMTA and Denver RTD.

SUMMARY OF RECOMMENDED PROCUREMENT STRATEGIES

Air-Streamlining

Temperature-sensitive Fans

Turbocharged Engines

Reduced Vehicle Weight

Evaporative-cooling Technology

Chapter 6

CONCLUSION

This manual has identified a number of possible ways to reduce fuel consumption in a revenue fleet. Some are complex and require time to implement; others require a decision and simple changes. Some can save hundreds of dollars per coach, while others will make only a modest difference.

The basic recommendation, in simple terms, is "Go try something." None of the measures discussed in this manual will save any fuel until they are implemented. The best approach is to pick one or two measures that seem appropriate to each fleet, try them and test them if necessary.

All transit systems should include improved driving as one element of their fuel-conservation program because it is low in cost and offers great potential for fuel savings. Because this approach requires behavioral changes by all drivers, they should be involved in its implementation.

In selecting other measures, begin with those with high-potential savings and a relatively easy process for testing and implementation. After initial efforts have been implemented or rejected, refer to this manual as a source of new approaches to take. And, share the manual with other staff to foster a broader knowledge of and support for a fuel-conservation program.

SUMMARY OF FUEL-CONSERVATION MEASURES

MAINTENANCE AND EQUIPMENT STRATEGIES

Aggressive Tune-up Program

Tire-pressure Maintenance

Manometer Air-filter Checks

Engine Rebuilds

Appropriate Fuel Injectors

Use of Radial Tires

Use of Higher-temperature Thermostats

Use of Throttle Delays

SUMMARY OF FUEL-CONSERVATION MEASURES (continued)

OPERATIONS STRATEGIES

Improved Driving Habits

- Reduced idling during layovers and at garages
- Smooth starts and stops
- Defensive driving
- Adherence to speed limits
- Downhill coasting
- Air conditioning off on uphill grades

Use of No. 2 Diesel

Improved Fueling

Traffic-flow Improvements through Planning

PROCUREMENT STRATEGIES

Air-streamlining

Temperature-sensitive Fans

Turbocharged Engines

Reduced Vehicle Weight

Evaporative-cooling Technology

APPENDIX A

Estimated Fuel Savings

Relatively little hard data are available on the amount of improvement in fuel efficiency likely to result for transit coaches from the various techniques discussed in this manual. By contrast, considerable testing has been done on truck fuel economy and a large amount of data has been compiled by the Joint Industry-Government Voluntary Truck and Bus Fuel Economy Improvement Program, an office of the National Highway Transportation Safety Administration. The Voluntary Program has published a number of documents describing fuel-saving strategies and calculating the percentage of fuel savings likely to result from their implementation. This manual uses data from several of their publications: "How To Save Truck Fuel," "Trucker's Guide to Fuel Savings," "New Trucks Save Fuel - 1978," "How To Save Gas and $$" (U.S. Department of Energy) and "17 Tricks To Saving Fuel." The figures in this manual are estimates extrapolated from data available to the trucking industry. This appendix describes the ways in which these figures were extrapolated for transit coaches.

Radial Tires

The following figures have been provided for calculating the increased fuel efficiency likely to result for trucks using radial tires:

Percentage of Savings for Trucks

Using Radial Tires	Source
4-6%	"New Trucks Save Fuel - 1978"
3-10%	"How to Save Gas and $$"
5.7%, 3-12%,6%*	"How to Save Truck Fuel"
9%, 8.1%*	"Trucker's Guide to Fuel Savings"

*Each of these figures was presented in the same publication.

The average of these estimates together is a 6.8 percent savings for trucks. Several factors probably mitigate the savings for transit coaches:

(1) A fully loaded bus weights less than half of a loaded truck (an estimated gross weight of 30,000 to 35,000 pounds compared with 72,000 to 80,000 pounds for long-haul trucks) so should experience proportionately less rolling resistance than a truck.

(2) Buses have fewer tires than trucks (six tires on a standard coach compared with 16 to 18 on a truck), which should also make the rolling resistance for buses proportionately less than that for trucks. Rolling resistance, air resistance and friction within the drive-train are major sources of energy inefficiency. If rolling resistance is a proportionately smaller share of total resistance for buses than for trucks, then the use of radial tires would represent a proportionately smaller reduction in total friction.

(3) Coaches, even when engaged in highway service, spend travel time in city traffic where radial tires have less effect on fuel efficiency.

Taking into account these factors, it can be conservatively estimated that radial tires will provide transit coaches with about half of the 6.8 percent in fuel savings they yield for trucks—still an estimated gain of three percent.

Temperature-sensitive Fans

Reports consistently state that temperature-sensitive fans in over-the-road trucks are running less than 5 percent of the time or conversely, are inactive at least 95 percent of the time. Estimates of the fuel savings vary somewhat.

Percentage of Savings for Trucks

Using Temperature-Sensitive Fans	Source
2-6%	"New Trucks Save Fuel - 1978"
7%	"How to Save Truck Fuel"
3-5%, 6.8%*	"Trucker's Guide to Fuel Savings"

*Each of these figures was presented in the same publication.

By averaging these figures, there is an approximate savings of 5.5 percent for trucks. Tests have not yet been done to determine how frequently these fans run in transit coaches. However, conversations with engineers at Cummins Engine Company and Detroit Diesel Allison suggest that 50 percent is a reasonable approximation for a typical coach. This estimate takes into account the fact that a bus engine is in the rear of the coach and does not benefit from air cooling. If a fan inactive 95 percent of the time in a truck reduces the truck's fuel consumption by 5.5 percent, then it is conservatively deduced that a fan inactive 50 percent of the time in a bus would reduce bus fuel consumption by about 3 percent.

For a coach in highway service, it is assumed that the fan would run considerably less than 50 percent of the time, bringing the likely fuel savings for highway coaches up to an estimated savings of 4 percent—closer to the savings for trucks.

Tire Pressure

Only one publication, "How to Save Gas and $$," offers a figure for fuel loss associated with underinflated tires. It states that underinflation by two psi reduces MPG by 1 percent. That figure was used for this manual.

Tune-ups

Figures for savings resulting from tuning up vehicles are somewhat limited. "How to Save Gas and $$" first puts it at 12 percent, then later states 4 percent. Another publication, "Gas Savers," offers 4 to 12 percent as the range. Since all coaches are not out of tune at the same time, using the percentage gain for a tuned vehicle would overstate the effect of a tune-up program. To be conservative, the fuel savings of an aggressive tune-up program is estimated to range from 2 to 4 percent.

REFERENCES

Publications of Cummins Engine Company, Inc., "Automotive Technical Sales Seminar on Truck Performance and Fuel Economy"

Publications of the Joint Industry-Government Voluntary Truck and Bus Fuel Economy Improvement Program:

"New Trucks Save Fuel - 1978"
"How To Save Truck Fuel"
"Gas Savers"
"Trucker's Guide To Fuel Savings"
"17 Tricks to Saving Fuel"
"Selected Issues of Fuel Economy News"
"New Trucks Save Fuel—1979"
"How to Save Gas and $$"

Note: The Voluntary Association can be contacted through the National Highway Traffic Safety Administration, U.S. Department of Transportation, NRD-11, Washington, D.C. 20590.

Publications of Trucksave, Ministry of Energy, Toronto, Ontario, Canada,
"Idling Costs $$$"

Publications of the U.S. Department of Energy, Washington, D.C.,
"How to Save Gasoline....and Money"

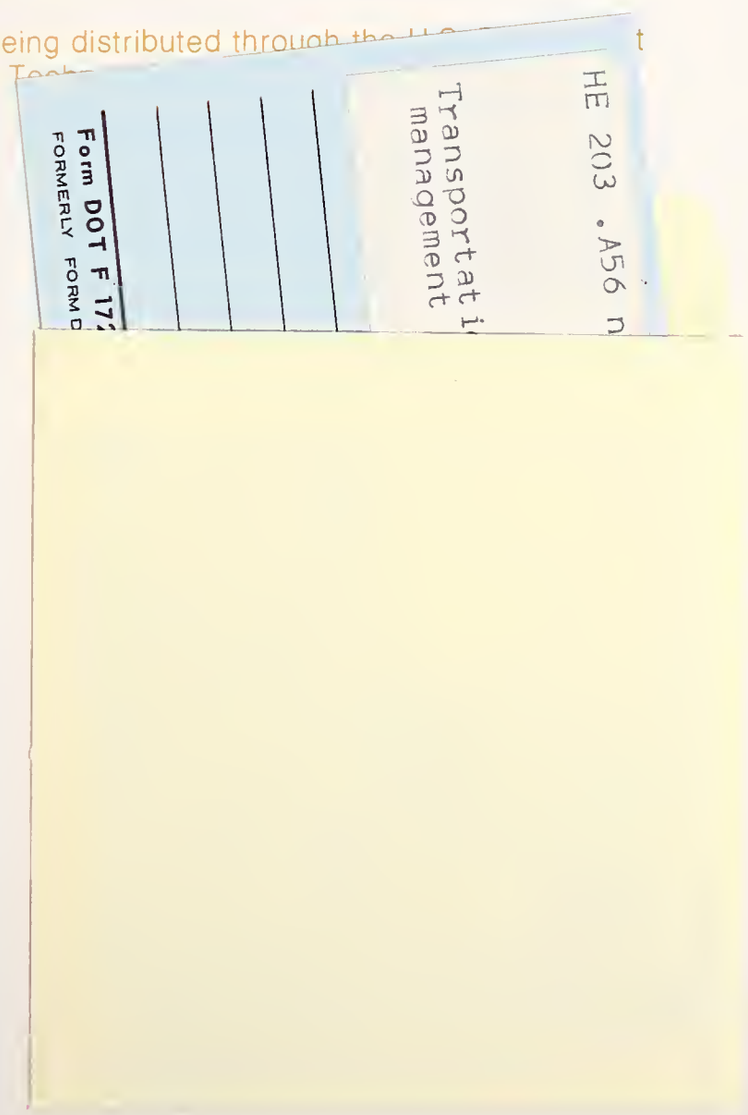
Publications of the U.S. Urban Mass Transportation Administration, Washington, D.C.
"Report on Potential Energy Savings by Mass Transit Operators in Region V,
"Office of Inspector General.

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

This document is being distributed through the U.S. Department of Transportation's Technology Sharing Program.

DOT-I-84-30



DOT-I-84-30

TECHNOLOGY SHARING

SPACIAL STUDIES IN TRANSPORTATION PLANNING (SSTP)

PROGRAM OF THE U.S. DEPARTMENT OF TRANSPORTATION